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- Sub A/
- 5 1. An elongated current limiting composite, comprising:
at least one oxide superconducting member; and
at least one second electrically conductive member substantially
surrounding the at least one oxide superconducting member,
wherein the composite exhibits an electric field in the range of about 0.05-
0.5 V/cm during a fault current limiting event, wherein a fault
current limiting event comprises passing about 3-10 times an
operating current through the composite, the operating current
selected to be less than or about equal to the critical current of the
oxide superconductor and greater than or about equal to one-half
the critical current of the oxide superconductor at a selected
operating temperature less than the critical temperature of the at
least one oxide superconducting member.
- 10 2. The composite of claim 1, wherein the second electrically conductive member
comprises a silver-containing matrix.
- 15 3. The composite of claim 2, wherein the silver-containing matrix further
includes at least one element selected from the group consisting of
gallium, tin, cadmium, zinc, indium, and antimony.
- 20 4. The composite of claim 2, wherein the second electrically conductive member
further comprises at least one bonding agent thermally connected to the
matrix.
- 25 5. The composite of claim 4, wherein the second electrically conductive member
further comprises at least one thermal stabilizing element thermally
connected to the at least one bonding agent.

6. The composite of claim 5, wherein the at least one thermal stabilizing element comprises stainless steel.

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7. The composite of claim 6, wherein the bonding agent comprises an adhesive or solder.

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8. The composite of claim 5, wherein the at least one thermal stabilizing element comprises a copper alloy containing at least 3 weight % titanium and 0-5 weight % silicon.

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9. The composite of claim 8, wherein the bonding agent comprises an adhesive or solder.

10. The composite of claim 5, wherein the composite is in the form of a wire.

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11. The composite of claim 1, wherein the heat capacity of the composite is sufficient to prevent the composite temperature from rising above the critical temperature of the at least one superconducting oxide member during a fault event.

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12. The composite of claim 11, wherein

$$C_p \times \text{density} \times [T_c - T_{op}] \times \frac{\rho_{el}}{V^2} > t$$

where C_p is the average specific heat for the composite, density is the average density for the composite, T_c is the critical temperature of the superconducting member, T_{op} is the operating temperature, ρ_{el} is the current dependent average resistivity of the composite,

averaged over the duration of a fault event of duration t , V is the voltage gradient along the composite, and t is about 50 msec.

13. The composite of claim 12, wherein t is about 150 msec.

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14. The composite of claim 12, wherein t is about 250 msec.

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15. The composite of claim 12, wherein t is about 500 msec.

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16. The composite of claim 12, wherein t is about 1000 msec.

17. The composite of claim 12, wherein t is about 2000 msec.

18. The composite of claim 1, wherein sufficient heat can be dissipated from the composite while carrying the operating current after a fault event to allow the composite to cool to the operating temperature.

19. The composite of claim 18, wherein

$$J_{op}^2 \times \rho_{el}^* < h \times (T_c - T_{op}) \times \alpha$$

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where J_{op} is the operating current density, h is the effective heat transfer coefficient of the composite, T_c is the critical temperature of the superconducting member, T_{op} is the operating temperature, α is the form factor of the composite, and ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 50 msec duration.

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- 5 20. The composite of claim 19, wherein ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 150 msec duration.
- 10 21. The composite of claim 19, wherein ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 250 msec duration.
- 15 22. The composite of claim 19, wherein ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 500 msec duration.
- 20 23. The composite of claim 19, wherein ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 1000 msec duration.
- 25 24. The composite of claim 19, wherein ρ_{el}^* is the current dependent average resistivity of the composite at the end of a fault event of 2000 msec duration.
26. The composite of claim 1, wherein the heat capacity of the composite is sufficient to prevent the composite temperature from rising above the critical temperature of the at least one superconducting oxide member during a fault event and wherein sufficient heat can be dissipated from the composite while carrying the operating current after a fault event to allow the composite to cool to the operating temperature.
26. The composite of claim 25, wherein

$$C_p \times \text{density} \times [T_c - T_{op}] \times \frac{\rho_{el}}{V^2} > t$$

and wherein

$$J_{op}^2 \times \rho_{el}^* < h \times (T_c - T_{op}) \times \alpha$$

where C_p is the average specific heat for the composite, density is the
5 average density for the composite, T_c is the critical temperature of
the superconducting member, T_{op} is the operating temperature, ρ_{el}
is the current dependent average resistivity of the composite,
averaged over the duration of a fault event of duration t , ρ_{el}^* is the
current dependent average resistivity of the composite at the end of
10 a fault event of duration t , V is the voltage gradient along the
composite, J_{op} is the operating current density, h is the effective
heat transfer coefficient of the composite, α is the form factor of
the composite, and t is about 50 msec.

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15 27. The composite of claim 26, wherein t is about 150 msec.

28. The composite of claim 26, wherein t is about 250 msec.

29. The composite of claim 26, wherein t is about 500 msec.

20 30. The composite of claim 26, wherein t is about 1000 msec.

31. The composite of claim 26, wherein t is about 2000 msec.

25 32. A current-limiting transformer comprising

a plurality of windings, wherein at least one winding comprises the composite of claim 1 in electrical series with the windings.

33. The transformer of claim 32, further comprising cooling means for holding
5 the composite at an operating temperature less than or about equal to the critical temperature of the oxide superconductor.

10 34. A current limiter suitable for being placed in series with a power transmission system, comprising
a current-limiting composite according to claim 1; and
cooling means for cooling the composite to an operating temperature less than or about equal to the critical temperature of the composite.

15 35. A method of limiting current during a fault event in a power transmission system carrying an operating current, comprising:
interposing a superconducting composite into the system in series with other components of the system, the composite comprising, a superconducting oxide member; and a second electrically conducting member substantially surrounding the superconducting oxide member,
20 wherein the superconducting composite is held at an operating temperature and carries the operating current with a voltage gradient of less than 1 V/cm in the absence of a fault, the operating current being at least about half of the critical current of the superconducting oxide member, and
25 wherein upon the occurrence of a fault in which the system carries a current of about 3-10 times the operating current, the voltage gradient in the superconducting composite is in the range of 0.05-0.5 V/cm.

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36. The method of claim 35, wherein the second electrically conductive member comprises a silver-containing matrix.
37. The method of claim 36, wherein the silver-containing matrix further includes at least one other element selected from the group consisting of gallium, tin, cadmium, zinc, indium, and antimony.
38. The method of claim 35, wherein the second electrically conductive member further comprises at least one bonding agent thermally connected to the matrix.
39. The method of claim 38, wherein the second electrically conductive member further comprises at least one thermal stabilizing element thermally connected to the at least one bonding agent.
40. The method of claim 39, wherein the at least one thermal stabilizing element comprises stainless steel.
41. The method of claim 40, wherein the bonding agent comprises an adhesive or solder.
42. The method of claim 39, wherein the at least one thermal stabilizing element comprises a copper alloy containing at least 3 weight % titanium and 0-5 weight % silicon.
43. The method of claim 42, wherein the bonding agent comprises an adhesive or solder.
44. The method of claim 35, wherein the composite material is in the form of a wire.

5 45. The method of claim 35, wherein the second electrically conductive member
is configured such that temperature of the at least one oxide
superconductor following a fault current limiting event is less than a
critical temperature of the at least one oxide superconductor.

10 46. The method of claim 35, wherein the power transmission system comprises a
circuit breaker in electrical series with the superconducting composite,
which interrupts current in response to a fault event.

15 47. The method of claim 46, wherein the time between the onset of a fault event
and the interruption of current by the circuit breaker is about 50-2000
msec.

20 48. The method of claim 46, wherein the time between the onset of a fault event
and the interruption of current by the circuit breaker is about 100-1000
msec.

25 49. The method of claim 46, wherein the time between the onset of a fault event
and the interruption of current by the circuit breaker is about 200-500
msec.